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HIGH TENSILE STRENGTH BOLT WITH LAGGING DESTRUCTION RESISTANCE CHARACTERISTICS AND MANUFACTURING METHOD THEREOF

[Taiokure hakai tokusei o yusuru kochoryoku boruto oyobi sono seizo hoho]

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Claims /2*

1. A high tensile strength bolt with lagging destruction resistance characteristics characterized in that the tensile strength of a heat treated rod material having a rolled thread at the end is 130 kgf/mm^2 or more, and wherein a surface layer, having as base material a low alloy steel containing 0.3-0.6 C and 1.2 or more Si, by wt%, as essential components, has a fine perlite structure, and the center part is a martensite structure having tensile strength of 150 kgf/mm^2 or more.

2. A manufacturing method for a high tensile strength bolt with lagging destruction resistance characteristics characterized in that hardening and tempering are applied over the entire cross section to a low alloy steel rod material containing 0.3-0.6 C and 1.2 or more Si, by wt%, as essential components to give a finish tensile strength of 150 kgf/mm^2 or more to said rod material; next, only the surface layer of the rod material is rapidly heated to a prescribed temperature higher than the aforementioned tempering temperature using a high-frequency induction heating means and is then quenched and re-tempered to give a fine pearlite structure, and then rolled thread processing is applied to the end of the rod material and a bolt with tensile strength of 130 kgf/mm^2 or more is produced.

3. A manufacturing method for a high tensile strength bolt with lagging destruction resistance characteristics characterized in that hardening and tempering are applied over the entire cross section to a low alloy steel rod material containing 0.3-0.6 C and 1.2 or more Si, by wt%, as essential components to give a finish tensile strength of 150 kgf/mm^2 or more to said rod material; next, only the surface layer of the rod material is rapidly heated to a prescribed temperature higher than the aforementioned tempering temperature using a high-frequency induction heating means and is then quenched and re-tempered to give a fine pearlite structure; then rolled thread processing is applied to the end of the rod material and a bolt is formed; and then bluing treatment is applied; and the tensile strength [of the bolt] is 130 kgf/mm^2.

* [Numbers in right margin indicate pagination of the original text.]

Detailed explanation of the invention /2

The present invention relates to a high tensile strength bolt with lagging destruction resistance characteristics, and to a manufacturing method thereof.

Recently, the demand for high tensile strength bolts has been increasing rapidly because of requirements, such as lighter weight parts. However, high tensile strength bolts appropriate corresponding to F13T (tensile strength of 130 kgf/mm^2 or more) as established by JIS standards are subject to frequency lagging destruction failures in application examples of the past, and at the present time measures prohibiting their use are in place.

When lagging destruction of a high tensile strength bolt is viewed from a materials aspect, the phenomenon of lagging destruction occurs in ones where σ_B is 120-130 kgf/mm^2, and as the strength level increases, the susceptibility to lagging destruction increases markedly. There seem to be two factors causing said lagging destruction phenomenon – (1) stress corrosion fractures that occur when the external environment is a corrosive atmosphere, and (2) hydrogen brittlement fractures caused by the steel material itself. The former is handled as a problem of the usage state. Referring only to the latter, the level of hydrogen content in the steel material naturally relates significantly to hydrogen brittlement fractures, and even with the same hydrogen content, as an example, the higher the strength level, the more readily hydrogen brittlement fractures occur, and higher fastening stress leads to the bolt breaking in a shorter time. Concerning this point, in the past, it has been stated that the higher the microscopic stress gradient inside the steel material is, the higher the degree of mobility of the hydrogen atoms, and they concentrate in areas of stress concentration, such as grain boundaries, and cause brittle destruction. To reduce the lagging destruction phenomenon, adding elemental Si to the steel material is effective, but the point has not yet been reached where the reliability of previous high tensile strength bolts composed of steel material with added Si is sufficiently assured.

In consideration of the aforementioned situation, the present inventors attempted to clarify the lagging destruction phenomenon so as to practically produce high tensile strength bolts with a tensile strength of 130 kgf/mm^2 or more practical. This is discussed below.

It is clear that adding Si to steel material aids in reducing susceptibility to lagging destruction. However, why is it that regardless of whether or not Si is added, when the strength of steel obtained by hardening and tempering is 120 kgf/mm^2 or less, the lagging destruction phenomenon is not much of a problem, and as strength becomes higher beyond 120 kgf/mm^2, susceptibility to lagging destruction increases? Viewed from this standpoint, it is obvious that the surface state of the steel material exerts a large influence on destruction and cannot be ignored. That is, it was determined that when a load is applied to a bolt, stress concentration occurs in tiny notches or pits in the steel material surface, and as the strength becomes higher beyond 120 kgf/mm^2, the degree of stress concentration abruptly increases according to the stress load, minute cracks occur with the aforementioned notches and pits as nuclei, and thus the susceptibility increases abruptly, leading to the appearance of the lagging destruction phenomenon.

The present inventors devised the present invention on the basis of the aforementioned determination, with the objective of eliminating the shortcoming present in conventional high tensile strength bolts, and thereby will provide a high tensile strength bolt with a higher strength than conventional articles and with which lagging destruction susceptibility is also significantly reduced.

The essential points of the first invention in this application are,

(1) A low alloy steel material containing 0.3-0.6 C and 1.2 or more Si, by wt%, as essential components is used as the base material,

(2) The surface layer is a fine pearlite structure,

(3) The center part is a martensite structure with tensile strength of 150 kgf/mm^2 or more,

(4) The tensile strength of the rod material that has a rolled thread at the end [and comprising the above] is 130 kgf/mm^2,

which characterize the high tensile strength bolt with lagging destruction resistance characteristics.

Then, the essential points of the second invention in this application, which is a method to manufacture the high tensile strength bolt of the first invention, are,

(1) To a low alloy steel rod material containing 0.3-0.6 C and 1.2 or more Si, by wt%, as essential components,

(2) Hardening and tempering are applied over the entire cross section to give a finish tensile strength for said rod material of 150 kgf/mm^2 or more,

(3) Next, only the surface layer of the rod material is heat treated by heating to a prescribed /3
temperature higher than the aforementioned tempering temperature with a high-frequency inducting heating means, it is then quenched and re-tempered, to produce a fine pearlite structure, and then

(4) Rolled thread machining is applied to the end of the rod material,

(5) A bolt with a tensile strength of 130 kgf/mm^2 or more is produced, which characterize

the manufacturing method for high tensile steel bolt with lagging destruction resistance characteristics.

This is described in detail below.

The base steel material used for the present invention is low alloy steel, and containing the elements below in the prescribed wt% is an essential condition.

C: 0.3-0.6%. The lower the C content, basically, the less readily lagging destruction will be caused, but to assure hardening ability in order to retain a tensile strength of 150 kgf/mm^2 or more, less than 0.3% is insufficient, and more than 0.6% is unnecessary.

Si: 1.2% or more. This is added as a ferrite strengthening element, and to restrict movement of incorporated hydrogen atoms as described above, and the content thereof is based on the test data below.

In short, a hot rolled steel rod 9.5 mm ϕ and containing the components shown in Table 1 was cleaned with acid and neutralized, and then it was cold drawn to 9.1 mm ϕ. Next hardening and tempering were performed using high-frequency induction heating, producing a test material with a tensile strength at the 150 kgf/mm^2 level, and otherwise meeting the mechanical properties required in steel rods for pre-stressed concrete. Then the claimed range of 1.2% or more Si where effects were noted was obtained from the line diagrams shown in Figures 1 (a) and (b) showing the relationship between fracture time and Si content in the steel material found from the results of stress corrosion fracture testing and lagging destruction testing using hydrogen charging performed for each of the test materials.

TABLE 1

No.	C	Si	Mn	P	S	Cr
1	0.39	1.10	0.80	0.028	0.022	—
2	0.36	2.23	0.79	0.034	0.022	—
3	0.43	0.55	0.73	0.026	0.023	—
4	0.44	2.17	0.76	0.020	0.023	0.47
5	0.37	1.46	0.79	0.022	0.024	—
6	0.37	1.31	0.73	0.033	0.026	0.38
7	0.35	1.67	0.71	0.021	0.031	—
8	0.43	1.19	0.42	0.022	0.024	—
9	0.43	1.53	0.44	0.021	0.023	—
10	0.43	1.83	0.43	0.020	0.027	—
11	0.35	0.90	0.73	0.027	0.024	—
12	0.33	1.57	0.71	0.031	0.024	—
13	0.34	1.75	0.49	0.014	0.006	1.25
14	0.34	1.85	0.50	0.014	0.008	1.73
15	0.34	2.48	0.54	0.015	0.006	1.27
16	0.43	1.86	0.53	0.014	0.004	0.55
17	0.32	1.76	0.57	0.012	0.013	—
18	0.44	1.73	0.60	0.014	0.023	—
19	0.32	1.54	0.79	0.013	0.003	—

Then the high tensile strength bolt of the present invention has a rolled thread at the end of the heat treated rod material composed of low alloy steel containing the aforementioned essential components, the surface layer is a fine perlite structure having a tensile strength of around 100 kgf/mm^2, for example, and the remaining portion to the center, excluding said surface layer, is a martensite structure with a tensile strength of 150 kgf/mm^2 or more. Viewed comprehensively, the strong point is that it is a bolt with a tensile strength of 130 kgf/mm^2 or more. This is because, based on the determination derived from the abovementioned study results by the present inventors, even when fine notches or pits, for example, are present in the surface of the steel rod material, if the strength of the surface of said steel rod material is around 100 kgf/mm^2, the degree of stress concentration will be low, so the occurrence of fine cracks with the aforementioned notches and pits as nuclei is hindered, and the susceptibility to lagging destruction is reduced. If the remaining potion to the center of said steel rod material, excluding the aforementioned surface layer, is kept at a tensile strength of 150 kgf/mm^2 or more, it is possible to make the bolt strength 130 kgf/mm^2 or more. In this way, in terms of the steel rod material internal structure, the movement of /4
incorporated hydrogen atoms is restricted by the addition of elemental Si, and at the surface, the extent of stress concentration is lowered by strength being suppressed. The synergistic effect of both assures a tensile strength of 130 kgf/mm^2 or more, and produces a high tensile strength bolt with excellent lagging destruction resistance characteristics.

The high tensile strength bolt pertaining to the present invention represented by a load-elongation curve corresponding to its strength is shown in Figure 2 (a). In the figure, the value kgf/mm^2 which is load converted to stress is schematically represented on the vertical axis, and the load-elongation curve for the center part only, the surface layer only, and the bolt itself totaling the two for a bolt with a tensile strength at the 130 kgf/mm^2 level are schematically represented on the horizontal axis as (A), (B) and (C), respectively, using elongation %. The cross section hardness distribution of the high tensile steel bolt

pertaining to the present invention is also shown in Figure 2 (b). In the figure, hardness H_{RC} is schematically represented on the vertical axis, and the hardness distribution curve of a bolt with a tensile strength at the 130 kgf/mm^2 level is schematically represented on the horizontal axis, using the distance in mm from the center of the rod material to both outer peripheries.

Next the manufacturing method for the high tensile strength bolt pertaining to the present invention that has the aforementioned characteristics will be described in detail below.

First, after normal pretreatment – that is, acid cleaning, neutralizing and drawing – of a rod material composed of low alloy steel containing 0.3-06.% C and 1.2% or more Si, by wt%, as essential components, said rod material undergoes hardening and tempering over the entire cross section to finish at a tensile strength of 150 kgf/mm^2. Next, only the surface layer of the rod material that has been hardened and tempered is rapidly heated to a prescribed temperature, which is higher than the tempering temperature applied during the aforementioned hardening, using a high-frequency induction heating means, and then it is quenched and re-tempered. The thickness of the aforementioned surface layer that has undergone re-tempering is relative to the diameter of the rod material, and is 1 mm or less, for example. If technically feasible, thinner is preferable, and by making it thinner, the bolt strength can be made higher. The objective of the aforementioned re-tempering is to produce a fine pearlite structure where the strength of only the rod material surface layer is lowered to around 100 kgf/mm^2, for example. For this reason, the heating temperature for the aforementioned re-tempering varies according to the type of steel, of course, so although it cannot be stated as one rate, it will be a high temperature of at least 100ºC or more higher than the tempering temperature during hardening. The heat treated rod material obtained in this way is made to a prescribed length, thread machining using rolling is applied to the end, and the finished product is produced. Working the thread using rolling is, of course, because rolling is easier than cutting, due to the rod material hardness, and a larger effective cross section area is produced than with a cut thread, and the

structure is strengthened by rolling. So the strength of the descending thread part is kept to a minimum, compared to that of the flat parts, which contributes to a reduction in lagging destruction susceptibility. The bolt obtained with the aforementioned manufacturing method is well provided with lagging destruction resistance with a tensile strength of 130 kgf/mm^2 or more.

To obtain a high tensile strength bolt or other tension material with super-high strength of 150 kgf/mm^2 or 180 kgf/mm^2 or more, for example, if the heating means for initially hardening the rod material provides rapid heating, for example, high-frequency induction heating or direct conduction heating, or rapid heating and quenching using the same means as for hardening, the steel material structure can be prevented from coarsening. So even when finished to 180 kgf/mm^2 or 200 kgf/mm^2 or more, a hardened rod material that meets various properties required for high tensile strength bolts or other tension materials, such as elongation and contraction, is obtained, and the surface layer of said hardened rod material may be re-tempered in the same way as described above to produce a finished product.

In the present invention, when the strength of the thread parts is kept approximately equal to that of the flat parts to obtain a stronger bolt, after rolled thread machining is applied to the rod material end, bluing treatment at 300-350℃ may be performed.

The present inventors performed the following experiments to confirm the effects of the present invention.

Application example

(1) Creating of test specimen

a. Base material: 9.5 ϕ hot rolled wire material where JIS standard S35C equivalent steel components in particular were adjusted to have 1.5 wt% Si, and 9.5 ϕ hot rolled steel wire equivalent to SCM 440H /5

were used. They were cleaned with acid and neutralized, and then made 9.2 ϕ by cold drawing. For Si addition, they were divided into two lots – test specimens (I) and (II), and the SCM 440H material was used as test specimen (III) as is. The trace content components in each test specimen was as described in Table 2.

TABLE 2

1 化学成分 / 2 供試体名	C	Si	Mn	P	S	Cr	Mo
(I) (II)	0.37	1.52	0.79	0.022	0.012		
(III)	0.39	0.32	0.76	0.020	0.012	0.98	026

Key: 1 Chemical component

2 Test specimen No.

b. Heat treatment: the manufacturing method of the present invention was implemented for wire material test specimen (I). Namely, for hardening and tempering, a high-frequency induction heating means was used to apply hardening and tempering. Then re-hardening was applied with a high-frequency induction heating means, but in said heat treatment, test specimens (I) were divided into two lots – a and b. Then hardening and tempering were performed. Test specimens (I)-a were finished to a tensile strength of 150 kgf/mm2, and test specimens (I)-b were finished to a tensile strength of 130 kgf/mm2. Then re-tempering at a prescribed temperature was applied to each test specimen (I)-a and (I)-b. The tempering temperature and re-tempering temperature for each are shown below.

Test specimen	(I)-a	(I)-b
Tempering temperature	530°C	580°C
Re-tempering temperature	720°C	720°C

Hardening and tempering were applied to both wire material test specimens (II) and (III) using the same high-frequency induction heating means, but both test specimens (II) and (III) were each heat treated divided into two lots, and they were finished to test specimens (II)-a and (II)-b and (III)-a and (III)-b with a tensile strength of 150 kgf/mm^2 and 130 kgf/mm^2, respectively.

c. Thread machining: aforementioned heat treated test specimen wire materials (I)-a, (I)-b, (II)-a, (II)-b, (III)-a and (III)-b were each cut to a prescribed length, and then M10 x 1.25 meter fine threads were cold plastic worked using a rolling die around the outer circumference of the test specimens.

(2) Lagging destruction test

A lagging destruction test using an ammonium rhodanide solution was applied to each of the aforementioned test specimens based on the test conditions below, and fracture time was measured.

Immersion solution: NH_4SCN 20%

Solution temperature: 50℃

Load on test specimen: 80% of actual weight of base material (wire material test specimen after hardening and tempering)

(3) Test results

As shown in Figure 3. In Figure 3, the fracture time for each test specimen is plotted on coordinates using fracture time *hr* for the vertical axis and the tensile strength kgf/mm^2 of the base material on the horizontal axis, and a trend curve for each classification is drawn. (I) is a trend curve for the test specimens implementing the present invention, while (II) and (III) are those based on the conventional method. The invented test specimen (I) is 4 times weaker than test specimen (III) at the tensile strength 130 $kgfr/mm^2$

level, and even for test specimen (II), the elapsed time until fracturing is 5 times greater. At the 150 kgf/mm^2 level, it is noted that elapsed time until fracture is 5 times and 2.5 times [greater], respectively, relative to test specimen (II) and (III).

From the experimental results above, it was confirmed for the present invention that for a bolt having elemental Si as an indispensable element, the lagging destruction resistance is inherently excellent, even for a bolt composed of Si, and that the lagging destruction resistance becomes particularly pronounced the higher the strength.

Note that Figure 3 is a hardness distribution curve showing measured results for hardness (HRC) of the base material cross section of test specimen (I)-a pertaining to the present invention.

With the high tensile strength bolt pertaining to the present invention, as described above, there is a tendency for lagging destruction susceptibility to decrease the higher the strength is, compared to previous products. The present invention provides the extremely remarkable result of responding to the demand for lighter weight for parts in the construction industry and other related industries with a high tensile strength bolt with lagging destruction resistance characteristics and a manufacturing method thereof with which the possibility of a repeal of the ban on use of bolts with F13T or greater strength, which are /6
prohibited from use due to the frequent occurrence of lagging destruction failures with previous products, may be anticipated.

<u>Brief description of the figures</u>

Figures 1 (a) and (b) are line diagrams showing the relationship between the Si content in the steel material as a gauge of the lagging destruction resistance reduction and stress corrosion fracture time, and the hydrogen brittlement fracture time using hydrogen charging. Figures 2 (a) and (b) are, respectively, a load-elongation curve diagram and a hardness distribution curve diagram schematically showing the

strength of this invented high tensile strength bolt. Figure 3 is a curve diagram showing the test results using an ammonium rhodanide solution to test the lagging destruction susceptibility of the test specimens implementing the present invention and test specimens for previous products. Figure 4 is a hardness distribution curve diagram in the cross section of the base material of test specimen (I)-a pertaining to the present invention.

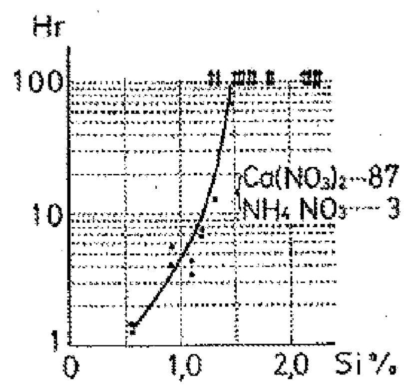

Figure 1a

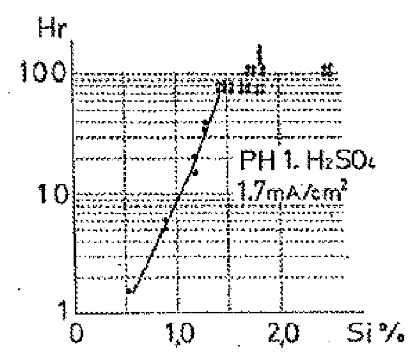

Figure 1b

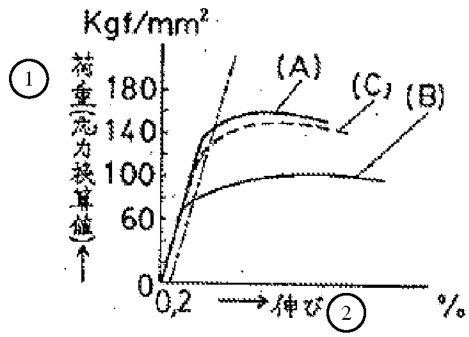

Figure 2a

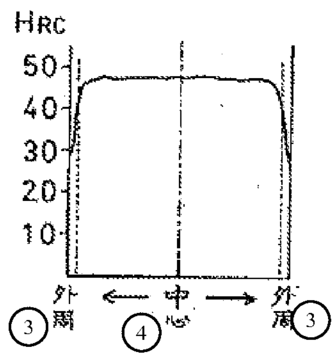

Figure 2b

Key: 1 Load (stress converted value)

2 Elongation

3 Outer periphery

4 Center

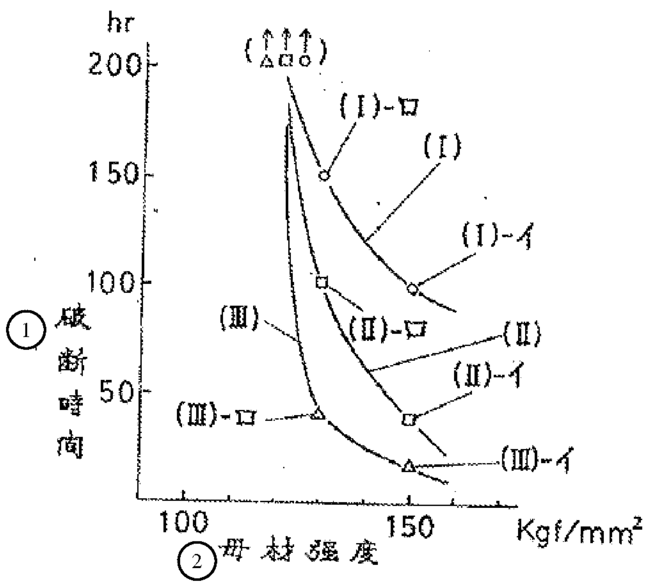

Figure 3

Key: 1 Fracture time

2 Base material strength

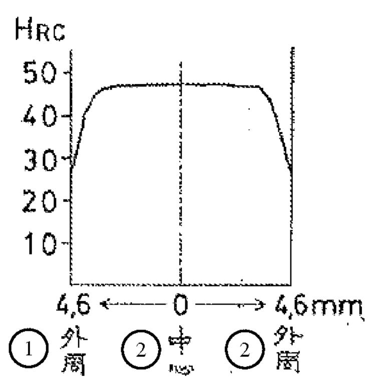

Figure 4

Key: 1 Outer periphery

2 Center

Amendment of April 27, 1983

5. Date of amendment

6. Subject of amendment

Detailed explanation of the invention and figures in the Specification.

7. Details of amendment

(1) Attached Figure 3 is replaced with the figure on the next page.

(2), (3) and (4) b. Heat treatment: the manufacturing method of the present invention was implemented for wire material test specimen (I). Namely, for hardening and tempering, a high-frequency induction heating means was used to apply hardening and tempering. Then re-hardening was applied with a high-frequency induction heating means, but in said heat treatment, test specimens (I) were divided into two lots – a and b. Then hardening and tempering were performed. Test specimens (I)-a were finished to a tensile strength of ~~150~~ **170** kgf/mm^2, and test specimens (I)-b were finished to a tensile strength of ~~130~~ **150** kgf/mm^2. Then re-tempering at a prescribed temperature was applied to each test specimen (I)-a and (I)-b, **corresponding to tensile hardness of 150 kgf/mm^2 and 130 kgf/mm^2**. The tempering temperature and re-tempering temperature for each are shown below.

End

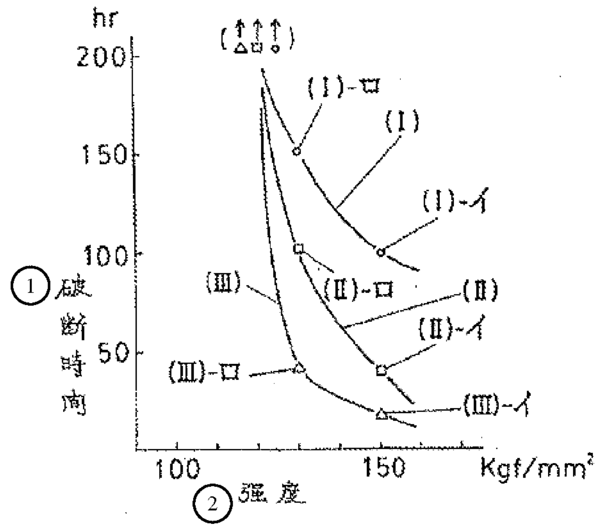

Figure 3

Key: 1 Fracture time

2 Strength

Amendment of April 28, 1984

5. Subject of amendment

Detailed explanation of the invention, Brief description of the figures, and Figure 4 and Figure 5 in the Specification.

6. Details of the amendment

(1) First, after normal pretreatment – that is, acid cleaning, neutralizing and drawing – of a rod material composed of low alloy steel containing 0.3-06.% C and 1.2% or more Si, by wt%, as essential components, said rod material undergoes hardening and tempering over the entire cross section to finish at a tensile

strength of 150 kgf/mm^2. Next, only the surface layer of the rod material that has been hardened and tempered is rapidly heated to a prescribed temperature, which is higher than the tempering temperature applied during the aforementioned hardening, using a high-frequency induction heating means, and then it is quenched and re-tempered. The thickness of the aforementioned surface layer that has undergone re-tempering is relative to the diameter of the rod material, and is 1 mm or less, for example. If technically feasible, thinner is preferable, **to the extent that a re-tempered layer will remain at the bottom of the threads with the thread rolling applied in a post-process,** and by making it thinner, bolt strength can be made higher.

(2) "Application example" → "Application Example.1"

(3) Hardening and tempering were applied to both wire material test specimens (II) and (III) using the same high-frequency induction heating means, but both test specimens (II) and (III) were each heat treated divided into two lots, and they were finished into test specimens (II)-a and (II)-b **and (III)-a and (III)-b, and each was cut to a prescribed length to give test specimens.** ~~and (III)-a and (III)-b with a tensile strength of 150 kgf/mm^2 and 130 kgf/mm^2, respectively.~~

~~c. Thread machining: aforementioned heat treated test specimen wire materials (I)-a, (I)-b, (II)-a, (II)-b, (III)-a and (III)-b were each cut to a prescribed length, and then M10 x 1.25 meter fine threads were cold plastic worked using a rolling die around the outer circumference of the test specimens.~~

(4) The present inventors additionally carried out the following experiment following aforementioned Application Example.1.

Application Example 2

(1) Test specimen

Heat treated wire materials (I)-a, (I)-b, (II)-a, (II)-b, (III)-a and (III)-b used for Application Example.1, and aforementioned (I) and (II) were the same up to the hardening process. As shown in Table 3, for (I), (I)-c with a different tempering process and re-tempering process, and for (II), (II)-c with a different tempering process were used, and after being cut to a prescribed length, and then M10 x 1.25 meter fine threads were cold plastic worked using a rolling die around the outer circumference of the test specimens.

TABLE 3

1 供試体	2 焼戻し温度℃	3 再焼戻し温度℃	4 母材仕上り引張り強さ kgf／mm²
(I)－ハ	490	720	165
(II)－ハ	490	——	165

Key: 1 Test specimen

2 Tempering temperature ℃

3 Re-tempering temperature ℃

4 Base material finish tensile strength kgf/mm^2

(2) Lagging destruction test

Using the same test method as Application Example 1.

(3) Test results

As shown in Figure 5. With Figure 5, the fracture time for each test specimen (N = 3) is plotted on coordinates using fracture time *hr* for the vertical axis and base material tensile strength *kgf/mm*^{2} for the horizontal axis, and a trend curve was found. (I) shows test results for the test specimens implementing the present invention, and (II) and (II) for the test specimens based on the conventional method.

From Figure 5, it was proven that lagging destruction resistance characteristics were increased with this invented test specimen (I) by cold rolled thread machining when the tensile strength is 130 kgf/mm^2, of course, as well as when 150 kgf/mm^2. At the 165 kgf/mm^2 tensile strength level, there was significant variation in the results, and it was noted that the limiting point is around 160 kgf/mm^2.

(5) Note that ~~Figure 3~~ Figure 5 is a hardness distribution curve showing measured results for hardness (HRC) of the base material cross section of test specimen (I)-a pertaining to the present invention.

(6) ~~Figure 3 is a curve diagram showing test results using an ammonium rhodanide solution to test the lagging destruction susceptibility of the test specimens implementing the present invention and test specimens for previous products. Figure 4 is a hardness distribution curve diagram in the cross section of the base material of test specimen (I)-a pertaining to the present invention.~~

Figure 3 and Figure 4 are line diagrams showing test results using an ammonium rhodanide solution to test lagging destruction susceptibility of each of the test specimens in application example 1 and application example 2, respectively. Figure 5 is a hardness distribution curve diagram in the cross section of the base material for test specimen (I)-a pertaining to the present invention.

(7) "Figure 4" in the Figures is amended to read "Figure 5," and the appended figure is added as Figure. 4. /10

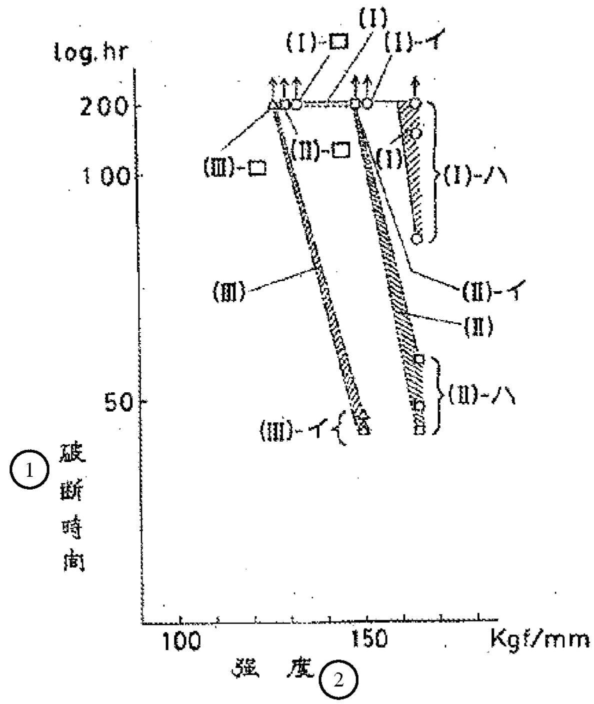

Figure 4

Key: 1 Fracture time

2 Strength

Amendment of July 12, 1984

5. Date of the amendment: June 5, 1984)

(Date mailed: June 12, 1984)

6. Subject of amendment

Amendment submitted on April 28, 1984, and Figure 5.

7. Details of the amendment

A copy on separate sheet with the figure number "Figure 4" for Figure 4 renamed "Figure 5" is hereby submitted. /11

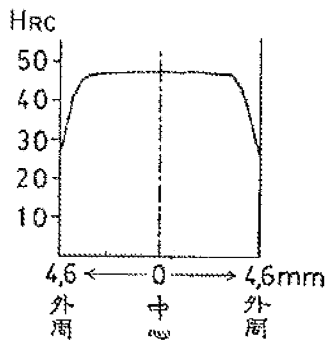

Figure 5

~~Figure 4~~

Key: 1 Outer periphery

2 Center